# PATENT ABSTRACTS OF JAPAN

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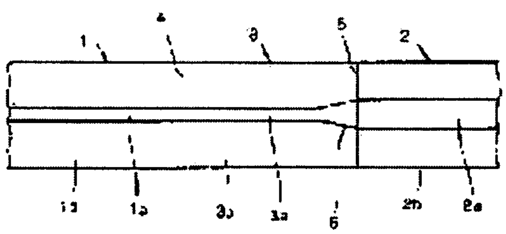
## (54) CONNECTING STRUCTURE AND CONNECTING METHOD OF DISPERSION COMPENSATION OPTICAL FIBER




(57)Abstract:

PURPOSE: To make it possible to connect a dispersion compensation optical fiber having a clad consisting of pure silica to an ordinary single mode optical fiber having a clad consisting of pure silica with low loss.

CONSTITUTION: The dispersion compensation optical fiber 1 having the clad 1b consisting of the pure silica and the single mode optical fiber 2 having the clad 2b consisting of the pure silica are fusion-spliced by interposing an intermediate optical fiber 3 having the same mode field diameter as the mode field diameter of the dispersion compensation optical fiber 1 and having the clad 3b consisting of fluorine doped silica and the core 3a consisting of GeO2-doped silica between both optical fibers 1 and 2 in the case of connecting both optical fibers 1, 2. The mode field diameter of the intermediate optical fiber 3 is expanded so as to meet the mode field diameter of the single mode optical fiber 2 by heating the juncture 5 of the intermediate optical fiber 3 and the single mode optical fiber 2.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CLAIMS

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[Claim(s)]
[Claim 1] A distributed compensation optical fiber with which a clad consists of a pure silica substantially A clad is a pure silica substantially. Are the connection structure of a distributed compensation optical fiber equipped with the above, and a diameter of the mode field is substantially [ as a diameter of the mode field of said distributed compensation optical fiber ] the same between said distributed compensation optical fibers and single-mode optical fiber. While making a middle optical fiber with which a clad consists of a fluorine dope silica, and a core consists of a silica containing a dopant which raises a refractive index intervene and carrying out fusion splicing of the end of a middle optical fiber to said distributed compensation optical fiber Fusion splicing of the other end of a middle optical fiber is carried out to said single-mode optical fiber, and it is characterized by expanding a diameter of the mode field of a middle optical fiber in a connection of a middle optical fiber and single-mode optical fiber so that a diameter of the mode field of single-mode optical fiber may be suited.
[Claim 2] A middle optical fiber is the connection structure of a distributed compensation optical fiber according to claim 1 characterized by being that by which a fluorine is doped by layer inside a path equivalent to a diameter of the mode field of single-mode optical fiber of a clad, and a fluorine is not substantially doped by layer outside it.
[Claim 3] A distributed compensation optical fiber with which a clad consists of a pure silica substantially A clad is a pure silica substantially. Are the connection method of a distributed compensation optical fiber equipped with the above, and a diameter of the mode field is substantially [ as a diameter of the mode field of said distributed compensation optical fiber ] the same between said distributed compensation optical fibers and single-mode optical fiber. While making a middle optical fiber with which a clad consists of a fluorine dope silica, and a core consists of a silica containing a dopant

which raises a refractive index intervene and carrying out fusion splicing of the end of a middle optical fiber to said distributed compensation optical fiber After carrying out fusion splicing of the other end of a middle optical fiber to said single-mode optical fiber, a connection of a middle optical fiber and single-mode optical fiber is heated. It is characterized by expanding a diameter of the mode field of a middle optical fiber in the connection so that a diameter of the mode field of single-mode optical fiber may be suited.
[Claim 4] A connection method of a distributed compensation optical fiber according to claim 3 characterized by using an optical fiber with which a fluorine is doped as a middle optical fiber by layer inside a path equivalent to a diameter of the mode field of single-mode optical fiber of a clad, and a fluorine is not substantially doped by layer outside it.

DETAILED DESCRIPTION

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[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the connection structure and the connection method of a distributed compensation optical fiber and usual single-mode optical fiber.
[0002]
[Description of the Prior Art] In order to attain large capacity-ization of an optical transmission system, performing a 1550nm high-speed communication link using the existing transmission line is examined. however, 1300nm 0 part diffused-light fiber laid widely now -- the mode dispersion near 1550nm -- about 18ps/nm/km -- for a certain reason, by 100km, it amounts to 1800 ps(es)/nm, and in performing a high-speed communication link, a certain distributed compensation means is needed.
[0003] It is the way being considered the method current but practical as a distributed compensation means inserts the distributed compensation optical fiber which has a negative high distribution property in the middle of a transmission line, and it offsets mode dispersion. Specifically making a distributed compensation optical fiber a small package, and including in transmission equipment is considered.
[0004] For the distributed compensation optical fiber with a negative high distribution property, delta (relative index difference) is as high as 3% order, and a core diameter is 2-3 micrometers. Compared with usual single-mode optical fiber, it is extremely small structure. Therefore, the 1550nm diameter of the mode field of a distributed compensation optical fiber is set to about 4.5-5.5 micrometers.
[0005] On the other hand, since the 1550nm diameter of the mode field of 1300nm 0 part diffused-light fiber is 9-11 micrometers, if the connector joint of this optical fiber and the distributed compensation optical fiber is carried out, big connection loss will produce it. Then, in order to prevent this, fusion splicing of a distributed compensation optical fiber and the usual single-mode optical fiber is carried out within a package, and the lead pulled out from a package is used as usual single-mode optical fiber, and makes possible the connector joint with a 1300 0 part diffused-light fiber.
[0006] In this case, the welding connection of a distributed compensation optical fiber and usual single-mode optical fiber expands the diameter of the mode field of a distributed compensation optical fiber, and he is trying to double it with the diameter of

the mode field of single-mode optical fiber by performing processing (TEC law) which it heats [ processing ] after connection and diffuses germanium incore. thereby, connection loss of a welding connection can be reduced sharply, and the total loss from a final connector input to a connector output is markedly looked like [ a distributed compensation optical fiber ] from what only carried out connector attachment, and is reduced.

[0007] By the way, a distributed compensation optical fiber is GeO2 to the core from the necessity of enlarging delta. The fluorine is doped by high concentration to the clad, respectively. When fusion splicing of such a distributed compensation optical fiber and the usual single-mode optical fiber (for a lead) is carried out and the connection is heated, the portion of the fluorine dope glass of a distributed compensation optical fiber has low softening temperature, and since glass structure is loose, it is GeO2. Diffusion is quick and expansion of the diameter of the mode field progresses for a short time. On the other hand, since the clad consists of pure silicas, the softening temperature of a clad is high, and usual single-mode optical fiber is GeO2. Diffusion cannot progress easily. Therefore, when fixed time amount heating of the connection is carried out, only the diameter of the mode field of a distributed compensation optical fiber is expanded, without expanding the diameter of the mode field of single-mode optical fiber. Consequently, it becomes possible to make connection loss of a welding connection small. Conventionally, this is the welding connection of a distributed compensation optical fiber and the single-mode optical fiber for a lead, and is the reason which can make connection loss small.

[0008]

[Problem(s) to be Solved by the Invention] However, a core is GeO2 as a recently and distribution compensation optical fiber because of a distributed property improvement. Using the optical fiber of the complicated structure where consist of a pin center,large core of a high concentration dope and a side core of a fluorine dope, and a clad consists of a pure silica called W mold is examined. Such a distributed compensation optical fiber is GeO2 of a pin center,large core, even if it heats a connection after carrying out fusion splicing to usual single-mode optical fiber since the outer diameter of the side core which doped the fluorine is about 5 micrometers and a clad is a pure silica. It is spread only to the side core which doped the fluorine. It is GeO2. If you are going to make it spread to a clad and heating time is lengthened, it will be GeO2 with the same said of the single-mode optical fiber for a lead. Diffusion will arise and the diameter of the mode field of single-mode optical fiber will be expanded similarly.

[0009] Therefore, in the distributed compensation optical fiber which a clad becomes from a pure silica, there was a problem that only a distributed compensation optical fiber could not expand the diameter of the mode field alternatively, and could not make connection loss low enough by the welding connection with the usual single-mode optical fiber with which a clad consists of a pure silica.

[0010] The purpose of this invention is to offer a means to connect the distributed compensation optical fiber with which a clad consists of a pure silica substantially with the usual single-mode optical fiber with which a clad consists of a pure silica substantially by low loss.

[0011]

[Means for Solving the Problem] A distributed compensation optical fiber with which a clad consists of a pure silica substantially in this invention in order to attain this purpose,

When connecting the usual single-mode optical fiber with which a clad consists of a pure silica substantially, between said distributed compensation optical fibers and single-mode optical fiber A middle optical fiber with which a diameter of the mode field is substantially [ as a diameter of the mode field of said distributed compensation optical fiber ] the same with an optical fiber, a clad consists of a fluorine dope silica, and a core consists of a silica containing dopants (GeO2 etc.) which raise a refractive index is made to intervene. And while carrying out fusion splicing of the end of a middle optical fiber to said distributed compensation optical fiber, fusion splicing of the other end of a middle optical fiber is carried out to said single-mode optical fiber. Furthermore, a diameter of the mode field of single-mode optical fiber in a connection of a middle optical fiber and single-mode optical fiber is expanded so that a diameter of the mode field of single-mode optical fiber may be suited. Expansion of this diameter of the mode field is performed by heating that connection after fusion splicing.

[0012] If connection structure of this invention is illustrated notionally, it will become like drawing 1 . a sign 1 -- a distributed compensation optical fiber -- it is -- GeO2 etc. -- clad 1b which becomes the periphery of core (or core which consists of side core which carried out fluorine dope with pin center,large core which doped GeO2 etc. to high concentration) 1a doped to high concentration from a pure silica is prepared. single-mode optical fiber usual in 2 -- it is -- GeO2 etc. -- clad 2b which becomes the periphery of doped core 2a from a pure silica is prepared. a diameter of the mode field of the distributed compensation optical fiber 1 is alike and smaller than a diameter of the mode field of single-mode optical fiber 2. 3 -- a middle optical fiber -- it is -- GeO2 etc. -- clad 3b which doped a fluorine is prepared in a periphery of core 3a doped to high concentration.

[0013] Moreover, a sign 4 is the portion which 6 expanded so that a welding connection of the distributed compensation optical fiber 1 and the middle optical fiber 3 and 5 might suit a welding connection of the middle optical fiber 3 and single-mode optical fiber 2 and a diameter of the mode field of single-mode optical fiber 2 might be suited in a diameter of the mode field of the middle optical fiber 3 by the connection 5 of the middle optical fiber 3 and single-mode optical fiber 2.

[0014]

[Function] Since the distributed compensation optical fiber 1 and the middle optical fiber 3 have the substantially the same diameter of the mode field, it is easy the optical fiber to connect these both by low loss 0.1dB or less by the usual fusion splicing.

[0015] On the other hand, since the dopants (GeO2 etc.) to which a fluorine is doped by the clad and the middle optical fiber 3 and usual single-mode optical fiber 2 raise a refractive index to a core although the diameters of the mode field differ are contained, if the middle optical fiber 3 is heated, it will be quicker than single-mode optical fiber 2, the dopant of a core will diffuse it in a clad, and the diameter of the mode field will expand it. Therefore, by heating the welding connection 5 of the middle optical fiber 3 and single-mode optical fiber 2, the diameter of the mode field of the middle optical fiber 3 can be expanded, and it can double with the diameter of the mode field of single-mode optical fiber 2. Connection loss in the condition of having doubled the diameter of the mode field can be made 0.2dB or less. Therefore, even if a welding connection becomes two places, total connection loss can be limited to about 0.3dB or less.

[0016] Since the connection loss at the time of carrying out direct fusion splicing of a

distributed compensation optical fiber and the usual single-mode optical fiber is 0.8dB or more, as compared with this, this invention can reduce connection loss sharply.
[0017]
[Example]
[Example 1] The following optical fibers were prepared.
** Distributed compensation optical fiber : a core is GeO2. A high concentration dope silica and a clad are a pure silica. delta= 3%, the diameter of the mode field = 5.0 micrometers.
** Usual single-mode optical fiber (for a lead) : a core is GeO2. A dope silica and a clad are a pure silica. delta= 0.4%, the diameter of the mode field = 10 micrometers.
** Middle optical fiber : a. core is GeO2. A high concentration dope silica [delta(+) =2.9] and a clad are a fluorine dope silica [delta(-) =0.1]. delta= 3%, the diameter of the mode field = 5.0 micrometers.
b. A core is GeO2. A high concentration dope silica [delta(+) =2.7] and a clad are a fluorine dope silica [delta(-) =0.3]. delta= 3%, the diameter of the mode field = 5.0 micrometers.
c. A core is GeO2. A high concentration dope silica [delta(+) =2.5] and a clad are a fluorine dope silica [delta(-) =0.5]. delta= 3%, the diameter of the mode field = 5.0 micrometers.
** Usual single-mode optical fiber (for transmission lines) : delta= 0.3%, diameter =of the mode field10micrometer.
[0018] The following samples were produced from these optical fibers.
Sample A: What carried out fusion splicing of the middle optical fiber of **-a to the both ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.
Sample B: What carried out fusion splicing of the middle optical fiber of **-b to the both ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.
Sample C: What carried out fusion splicing of the middle optical fiber of **-c to the both ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.
[0019] The result of having measured connection loss of the welding connection of each sample was as in a table 1. according to this result -- the amount of fluorine dopes to the clad of a middle optical fiber -- the reduction effect of connection loss of a minute amount -- it is (sample A) -- when it becomes more than delta(-) =0.3% (samples B and C), it turns out that the reduction effect of connection loss is stabilized on good level.
[0020]

[A table 1]

| | ①と③間の接続損失 | ③と②間の接続損失 | 合計接続損失 |
|---|---|---|---|
| サンプルA | 0．10dB | 0．35dB | 0．45dB |
| サンプルB | 0．13 | 0．15 | 0．28 |
| サンプルC | 0．15 | 0．15 | 0．25 |

[0021] Moreover, as a result of carrying out the connector joint of the connector to installation and the single-mode optical fiber of ** to the both ends of each sample, the sum total connection loss containing the connector in one side of a distributed compensation optical fiber was 0.65-0.45dB. This result is a good thing almost called below one half in connection loss compared with the following examples 1 and 2 of a comparison.
[0022] [Example 1 of a comparison] When installation, and the single-mode optical fiber and the connector joint of ** were performed for the connector to the both ends of the distributed compensation optical fiber of ** of an example 1, connection loss showed 1.2dB and a big value at one side.
[0023] [Example 2 of a comparison] When fusion splicing of the single-mode optical fiber for a lead of ** was carried out to the both ends of the distributed compensation optical fiber of ** of an example 1, connection loss showed 1.2dB and a big value at one side. Moreover, when the welding connection was heated, connection loss fell to 1.0dB with heating for about 1 minute, but when heating was continued further, connection loss increased to reverse. This is GeO2 of the core of single-mode optical fiber. It is because it was greatly spread to the clad, delta fell and the leakage of light became large. Therefore, connection loss was not able to be set to 1dB or less by this method.
[0024] Moreover, when the connector was attached in the both ends of the sample which carried out fusion splicing of the single-mode optical fiber for a lead of **, heated the welding connection to the both ends of the distributed compensation optical fiber of ** of an example 1, and set connection loss to 1.0dB to them and the connector joint was carried out to the single-mode optical fiber of **, the sum total connection loss containing the connector in one side of a distributed compensation optical fiber was 1.2dB in min.
[0025] [Example 2] The following distributed compensation optical fiber was prepared instead of the distributed compensation optical fiber of ** of an example 1.
** Distributed compensation optical fiber : a pin center,large core is GeO2. For high concentration dope [delta(+) =3%] and a silica, and a side core, fluorine dope [delta(-) =0.3%] and a silica, and a clad are W mold of a pure silica. The diameter of the mode field = 5.0 micrometers.
In addition, the optical fiber of ** of an example 1, **, and ** was prepared.
[0026] The following samples were produced from these optical fibers.
Sample D: What carried out fusion splicing of the middle optical fiber of **-a to the both ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded

the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.
Sample E: What carried out fusion splicing of the middle optical fiber of **-b to the both ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.
Sample F: What carried out fusion splicing of the middle optical fiber of **-c to the both ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.
[0027] The result of having measured connection loss of the welding connection of each sample was as in a table 2. from this result -- the amount of fluorine dopes to the clad of a middle optical fiber -- the reduction effect of connection loss of a minute amount -- it is (sample D) -- when it becomes more than delta(-) =0.3% (samples E and F), it turns out that the reduction effect of connection loss is stabilized on good level.
[0028]
[A table 2]

| | ⑤と③間の接続損失 | ③と②間の接続損失 | 合計接続損失 |
|---|---|---|---|
| サンプルD | ０．１０dB | ０．３５dB | ０．４５dB |
| サンプルE | ０．１１ | ０．１５ | ０．２６ |
| サンプルF | ０．１３ | ０．１５ | ０．２８ |

[0029] Moreover, as a result of carrying out the connector joint of the connector to the single-mode optical fiber of ** of installation and an example 1 to the both ends of each sample, the sum total connection loss containing the connector in one side of a distributed compensation optical fiber was 0.65-0.42dB. This result is a good thing almost called below one half in connection loss compared with the following examples 3 and 4 of a comparison.
[0030] [Example 3 of a comparison] When installation, and the single-mode optical fiber and the connector joint of ** of an example 1 were performed for the connector to the both ends of the distributed compensation optical fiber of ** of an example 2, connection loss showed 1.3dB and a big value at one end.
[0031] [Example 4 of a comparison] When fusion splicing of the single-mode optical fiber for a lead of ** of an example 1 was carried out to the both ends of the distributed compensation optical fiber of ** of an example 2, connection loss showed 1.1dB and a big value at one end. Moreover, even if it heats a welding connection, when connection loss does not fall but continues heating, it is GeO2 of the core of single-mode optical fiber. Connection loss is 1.3dB or more by diffusion.
[0032] Moreover, when the connector was attached in the both ends of the sample which

carried out fusion splicing of the single-mode optical fiber for a lead of ** of an example 1 and the connector joint was carried out to the single-mode optical fiber of ** of an example 1 to the both ends of the distributed compensation optical fiber of ** of an example 2, the sum total connection loss containing the connector in one side of a distributed compensation optical fiber was 1.3dB in min.

[0033] In addition, although the optical fiber which doped the fluorine was used for the whole clad as a middle optical fiber in the above example, it is desirable to use the optical fiber with which a fluorine is doped as a middle optical fiber by the layer inside the path equivalent to the diameter of the mode field of single-mode optical fiber of a clad, and the fluorine is not substantially doped by the layer outside it. When are done in this way and a welding connection with single-mode optical fiber is heated, the range which the dopant of the core of a middle optical fiber diffuses in a clad is restricted, and it becomes easy to double the diameter of the mode field of a middle optical fiber with the diameter of the mode field of single-mode optical fiber.

[0034]

[Effect of the Invention] As explained above, when connecting the distributed compensation optical fiber with which a clad consists of a pure silica substantially with the usual single-mode optical fiber with which a clad consists of a pure silica substantially according to this invention, it is effective in being connectable by low loss.

## TECHNICAL FIELD

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[Industrial Application] This invention relates to the connection structure and the connection method of a distributed compensation optical fiber and usual single-mode optical fiber.

## PRIOR ART

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[Description of the Prior Art] In order to attain large capacity-ization of an optical transmission system, performing a 1550nm high-speed communication link using the existing transmission line is examined. however, 1300nm 0 part diffused-light fiber laid widely now -- the mode dispersion near 1550nm -- about 18ps/nm/km -- for a certain reason, by 100km, it amounts to 1800 ps(es)/nm, and in performing a high-speed communication link, a certain distributed compensation means is needed.

[0003] It is the way being considered the method current but practical as a distributed compensation means inserts the distributed compensation optical fiber which has a negative high distribution property in the middle of a transmission line, and it offsets mode dispersion. Specifically making a distributed compensation optical fiber a small package, and including in transmission equipment is considered.

[0004] For the distributed compensation optical fiber with a negative high distribution property, delta (relative index difference) is as high as 3% order, and a core diameter is 2-3 micrometers. Compared with usual single-mode optical fiber, it is extremely small structure. Therefore, the 1550nm diameter of the mode field of a distributed compensation optical fiber is set to about 4.5-5.5 micrometers.

[0005] On the other hand, since the 1550nm diameter of the mode field of 1300nm 0 part diffused-light fiber is 9-11 micrometers, if the connector joint of this optical fiber and the

distributed compensation optical fiber is carried out, big connection loss will produce it. Then, in order to prevent this, fusion splicing of a distributed compensation optical fiber and the usual single-mode optical fiber is carried out within a package, and the lead pulled out from a package is used as usual single-mode optical fiber, and makes possible the connector joint with a 1300 0 part diffused-light fiber.

[0006] In this case, the welding connection of a distributed compensation optical fiber and usual single-mode optical fiber expands the diameter of the mode field of a distributed compensation optical fiber, and he is trying to double it with the diameter of the mode field of single-mode optical fiber by performing processing (TEC law) which it heats [ processing ] after connection and diffuses germanium incore. thereby, connection loss of a welding connection can be reduced sharply, and the total loss from a final connector input to a connector output is markedly looked like [ a distributed compensation optical fiber ] from what only carried out connector attachment, and is reduced.

[0007] By the way, a distributed compensation optical fiber is GeO2 to the core from the necessity of enlarging delta. The fluorine is doped by high concentration to the clad, respectively. When fusion splicing of such a distributed compensation optical fiber and the usual single-mode optical fiber (for a lead) is carried out and the connection is heated, the portion of the fluorine dope glass of a distributed compensation optical fiber has low softening temperature, and since glass structure is loose, it is GeO2. Diffusion is quick and expansion of the diameter of the mode field progresses for a short time. On the other hand, since the clad consists of pure silicas, the softening temperature of a clad is high, and usual single-mode optical fiber is GeO2. Diffusion cannot progress easily. Therefore, when fixed time amount heating of the connection is carried out, only the diameter of the mode field of a distributed compensation optical fiber is expanded, without expanding the diameter of the mode field of single-mode optical fiber. Consequently, it becomes possible to make connection loss of a welding connection small. Conventionally, this is the welding connection of a distributed compensation optical fiber and the single-mode optical fiber for a lead, and is the reason which can make connection loss small.

## EFFECT OF THE INVENTION

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[Effect of the Invention] As explained above, when connecting the distributed compensation optical fiber with which a clad consists of a pure silica substantially with the usual single-mode optical fiber with which a clad consists of a pure silica substantially according to this invention, it is effective in being connectable by low loss.

## TECHNICAL PROBLEM

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[Problem(s) to be Solved by the Invention] However, a core is GeO2 as a recently and distribution compensation optical fiber because of a distributed property improvement. Using the optical fiber of the complicated structure where consist of a pin center,large core of a high concentration dope and a side core of a fluorine dope, and a clad consists of a pure silica called W mold is examined. Such a distributed compensation optical fiber is GeO2 of a pin center,large core, even if it heats a connection after carrying out fusion splicing to usual single-mode optical fiber since the outer diameter of the side core which

doped the fluorine is about 5 micrometers and a clad is a pure silica. It is spread only to the side core which doped the fluorine. It is GeO2. If you are going to make it spread to a clad and heating time is lengthened, it will be GeO2 with the same said of the single-mode optical fiber for a lead. Diffusion will arise and the diameter of the mode field of single-mode optical fiber will be expanded similarly.
[0009] Therefore, in the distributed compensation optical fiber which a clad becomes from a pure silica, there was a problem that only a distributed compensation optical fiber could not expand the diameter of the mode field alternatively, and could not make connection loss low enough by the welding connection with the usual single-mode optical fiber with which a clad consists of a pure silica.
[0010] The purpose of this invention is to offer a means to connect the distributed compensation optical fiber with which a clad consists of a pure silica substantially with the usual single-mode optical fiber with which a clad consists of a pure silica substantially by low loss.

MEANS

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[Means for Solving the Problem] A distributed compensation optical fiber with which a clad consists of a pure silica substantially in this invention in order to attain this purpose, When connecting the usual single-mode optical fiber with which a clad consists of a pure silica substantially, between said distributed compensation optical fibers and single-mode optical fiber A middle optical fiber with which a diameter of the mode field is substantially [ as a diameter of the mode field of said distributed compensation optical fiber ] the same with an optical fiber, a clad consists of a fluorine dope silica, and a core consists of a silica containing dopants (GeO2 etc.) which raise a refractive index is made to intervene. And while carrying out fusion splicing of the end of a middle optical fiber to said distributed compensation optical fiber, fusion splicing of the other end of a middle optical fiber is carried out to said single-mode optical fiber. Furthermore, a diameter of the mode field of single-mode optical fiber in a connection of a middle optical fiber and single-mode optical fiber is expanded so that a diameter of the mode field of single-mode optical fiber may be suited. Expansion of this diameter of the mode field is performed by heating that connection after fusion splicing.
[0012] If connection structure of this invention is illustrated notionally, it will become like drawing 1 . a sign 1 -- a distributed compensation optical fiber -- it is -- GeO2 etc. -- clad 1b which becomes the periphery of core (or core which consists of side core which carried out fluorine dope with pin center,large core which doped GeO2 etc. to high concentration) 1a doped to high concentration from a pure silica is prepared. single-mode optical fiber usual in 2 -- it is -- GeO2 etc. -- clad 2b which becomes the periphery of doped core 2a from a pure silica is prepared. a diameter of the mode field of the distributed compensation optical fiber 1 is alike and smaller than a diameter of the mode field of single-mode optical fiber 2. 3 -- a middle optical fiber -- it is -- GeO2 etc. -- clad 3b which doped a fluorine is prepared in a periphery of core 3a doped to high concentration.
[0013] Moreover, a sign 4 is the portion which 6 expanded so that a welding connection of the distributed compensation optical fiber 1 and the middle optical fiber 3 and 5 might suit a welding connection of the middle optical fiber 3 and single-mode optical fiber 2

and a diameter of the mode field of single-mode optical fiber 2 might be suited in a diameter of the mode field of the middle optical fiber 3 by the connection 5 of the middle optical fiber 3 and single-mode optical fiber 2.

## OPERATION

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[Function] Since the distributed compensation optical fiber 1 and the middle optical fiber 3 have the substantially the same diameter of the mode field, it is easy the optical fiber to connect these both by low loss 0.1dB or less by the usual fusion splicing.
[0015] On the other hand, since the dopants ($GeO_2$ etc.) to which a fluorine is doped by the clad and the middle optical fiber 3 and usual single-mode optical fiber 2 raise a refractive index to a core although the diameters of the mode field differ are contained, if the middle optical fiber 3 is heated, it will be quicker than single-mode optical fiber 2, the dopant of a core will diffuse it in a clad, and the diameter of the mode field will expand it. Therefore, by heating the welding connection 5 of the middle optical fiber 3 and single-mode optical fiber 2, the diameter of the mode field of the middle optical fiber 3 can be expanded, and it can double with the diameter of the mode field of single-mode optical fiber 2. Connection loss in the condition of having doubled the diameter of the mode field can be made 0.2dB or less. Therefore, even if a welding connection becomes two places, total connection loss can be limited to about 0.3dB or less.
[0016] Since the connection loss at the time of carrying out direct fusion splicing of a distributed compensation optical fiber and the usual single-mode optical fiber is 0.8dB or more, as compared with this, this invention can reduce connection loss sharply.

## EXAMPLE

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[Example]
[Example 1] The following optical fibers were prepared.
** Distributed compensation optical fiber : a core is $GeO_2$. A high concentration dope silica and a clad are a pure silica. delta= 3%, the diameter of the mode field = 5.0 micrometers.
** Usual single-mode optical fiber (for a lead) : a core is $GeO_2$. A dope silica and a clad are a pure silica. delta= 0.4%, the diameter of the mode field = 10 micrometers.
** Middle optical fiber : a. core is $GeO_2$. A high concentration dope silica [delta(+) =2.9] and a clad are a fluorine dope silica [delta(-) =0.1]. delta= 3%, the diameter of the mode field = 5.0 micrometers.
b. A core is $GeO_2$. A high concentration dope silica [delta(+) =2.7] and a clad are a fluorine dope silica [delta(-) =0.3]. delta= 3%, the diameter of the mode field = 5.0 micrometers.
c. A core is $GeO_2$. A high concentration dope silica [delta(+) =2.5] and a clad are a fluorine dope silica [delta(-) =0.5]. delta= 3%, the diameter of the mode field = 5.0 micrometers.
** Usual single-mode optical fiber (for transmission lines) : delta= 0.3%, diameter =of the mode field10micrometer.
[0018] The following samples were produced from these optical fibers.
Sample A: What carried out fusion splicing of the middle optical fiber of **-a to the both

ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.

Sample B: What carried out fusion splicing of the middle optical fiber of **-b to the both ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.

Sample C: What carried out fusion splicing of the middle optical fiber of **-c to the both ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.

[0019] The result of having measured connection loss of the welding connection of each sample was as in a table 1. according to this result -- the amount of fluorine dopes to the clad of a middle optical fiber -- the reduction effect of connection loss of a minute amount -- it is (sample A) -- when it becomes more than delta(-) =0.3% (samples B and C), it turns out that the reduction effect of connection loss is stabilized on good level.

[0020]

[A table 1]

| | ①と③間の接続損失 | ③と②間の接続損失 |
|---|---|---|
| サンプルA | 0．10dB | 0．35dB |
| サンプルB | 0．13 | 0．15 |
| サンプルC | 0．15 | 0．15 |

[0021] Moreover, as a result of carrying out the connector joint of the connector to installation and the single-mode optical fiber of ** to the both ends of each sample, the sum total connection loss containing the connector in one side of a distributed compensation optical fiber was 0.65-0.45dB. This result is a good thing almost called below one half in connection loss compared with the following examples 1 and 2 of a comparison.

[0022] [Example 1 of a comparison] When installation, and the single-mode optical fiber and the connector joint of ** were performed for the connector to the both ends of the distributed compensation optical fiber of ** of an example 1, connection loss showed 1.2dB and a big value at one side.
[0023] [Example 2 of a comparison] When fusion splicing of the single-mode optical fiber for a lead of ** was carried out to the both ends of the distributed compensation optical fiber of ** of an example 1, connection loss showed 1.2dB and a big value at one side. Moreover, when the welding connection was heated, connection loss fell to 1.0dB with heating for about 1 minute, but when heating was continued further, connection loss increased to reverse. This is GeO2 of the core of single-mode optical fiber. It is because it was greatly spread to the clad, delta fell and the leakage of light became large. Therefore, connection loss was not able to be set to 1dB or less by this method.
[0024] Moreover, when the connector was attached in the both ends of the sample which carried out fusion splicing of the single-mode optical fiber for a lead of **, heated the welding connection to the both ends of the distributed compensation optical fiber of ** of an example 1, and set connection loss to 1.0dB to them and the connector joint was carried out to the single-mode optical fiber of **, the sum total connection loss containing the connector in one side of a distributed compensation optical fiber was 1.2dB in min.
[0025] [Example 2] The following distributed compensation optical fiber was prepared instead of the distributed compensation optical fiber of ** of an example 1.
** Distributed compensation optical fiber : a pin center,large core is GeO2. For high concentration dope [delta(+) =3%] and a silica, and a side core, fluorine dope [delta(-) =0.3%] and a silica, and a clad are W mold of a pure silica. The diameter of the mode field = 5.0 micrometers.
In addition, the optical fiber of ** of an example 1, **, and ** was prepared.
[0026] The following samples were produced from these optical fibers.
Sample D: What carried out fusion splicing of the middle optical fiber of **-a to the both ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.
Sample E: What carried out fusion splicing of the middle optical fiber of **-b to the both ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.
Sample F: What carried out fusion splicing of the middle optical fiber of **-c to the both ends of the distributed compensation optical fiber of **, carried out fusion splicing of the single-mode optical fiber of ** to the outer edge of a middle optical fiber further, heated the welding connection of a middle optical fiber and single-mode optical fiber, expanded the diameter of the mode field of a middle optical fiber, and was doubled with the diameter of the mode field of single-mode optical fiber.
[0027] The result of having measured connection loss of the welding connection of each

sample was as in a table 2. from this result -- the amount of fluorine dopes to the clad of a middle optical fiber -- the reduction effect of connection loss of a minute amount -- it is (sample D) -- when it becomes more than delta(-) =0.3% (samples E and F), it turns out that the reduction effect of connection loss is stabilized on good level.

[0028]

[A table 2]

| | ⑤と③間の接続損失 | ③と②間の接続損失 | 合計接続損失 |
|---|---|---|---|
| サンプルD | 0. 10dB | 0. 35dB | 0. 45dB |
| サンプルE | 0. 11 | 0. 15 | 0. 26 |
| サンプルF | 0. 13 | 0. 15 | 0. 28 |

[0029] Moreover, as a result of carrying out the connector joint of the connector to the single-mode optical fiber of ** of installation and an example 1 to the both ends of each sample, the sum total connection loss containing the connector in one side of a distributed compensation optical fiber was 0.65-0.42dB. This result is a good thing almost called below one half in connection loss compared with the following examples 3 and 4 of a comparison.

[0030] [Example 3 of a comparison] When installation, and the single-mode optical fiber and the connector joint of ** of an example 1 were performed for the connector to the both ends of the distributed compensation optical fiber of ** of an example 2, connection loss showed 1.3dB and a big value at one end.

[0031] [Example 4 of a comparison] When fusion splicing of the single-mode optical fiber for a lead of ** of an example 1 was carried out to the both ends of the distributed compensation optical fiber of ** of an example 2, connection loss showed 1.1dB and a big value at one end. Moreover, even if it heats a welding connection, when connection loss does not fall but continues heating, it is GeO2 of the core of single-mode optical fiber. Connection loss is 1.3dB or more by diffusion.

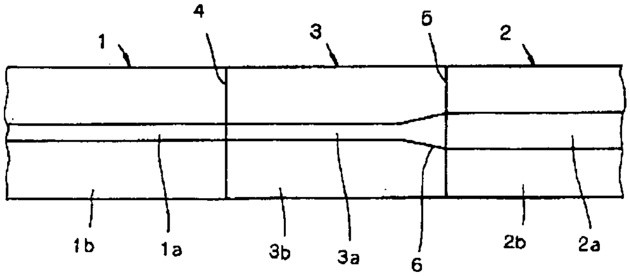
[0032] Moreover, when the connector was attached in the both ends of the sample which carried out fusion splicing of the single-mode optical fiber for a lead of ** of an example 1 and the connector joint was carried out to the single-mode optical fiber of ** of an example 1 to the both ends of the distributed compensation optical fiber of ** of an example 2, the sum total connection loss containing the connector in one side of a distributed compensation optical fiber was 1.3dB in min.

[0033] In addition, although the optical fiber which doped the fluorine was used for the whole clad as a middle optical fiber in the above example, it is desirable to use the optical fiber with which a fluorine is doped as a middle optical fiber by the layer inside the path equivalent to the diameter of the mode field of single-mode optical fiber of a clad, and the fluorine is not substantially doped by the layer outside it. When are done in this way and a welding connection with single-mode optical fiber is heated, the range which the dopant of the core of a middle optical fiber diffuses in a clad is restricted, and it becomes easy to double the diameter of the mode field of a middle optical fiber with the diameter of the mode field of single-mode optical fiber.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] Explanatory drawing showing the connection structure of the distributed compensation optical fiber by this invention.
[Description of Notations]
1: Distributed compensation optical fiber
1a: Core
1b: Clad
2: Usual single-mode optical fiber
2a: Core
2b: Clad
3: Middle optical fiber
3a: Core
3b: Clad
4 5: Welding connection
6: Diameter limb of the mode field

Drawing selection drawing 1




[Translation done.]

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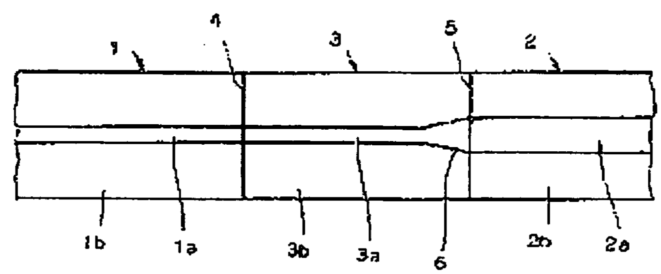
(54)【発明の名称】　分散補償光ファイバの接続構造および接続方法

(57)【要約】

【構成】　クラッド１ａが純シリカの分散補償光ファイバ１と、クラッド２ａが純シリカの単一モード光ファイバ２とを接続する場合に、両光ファイバ１、２間に、モードフィールド径が分散補償光ファイバ１と同じで、クラッド３ｂがフッ素ドープシリカ、コア３ａが$GeO_2$ドープシリカの中間光ファイバ３を介在させ、融着接続する。中間光ファイバ３と単一モード光ファイバ２の接続部５を加熱して、中間光ファイバ３のモードフィールド径を単一モード光ファイバ２のモードフィールド径に合うように拡大する。

【効果】　クラッドが純シリカからなる分散補償光ファ



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【特許請求の範囲】

【請求項１】クラッドが実質的に純シリカからなる分散補償光ファイバと、クラッドが実質的に純シリカからなる通常の単一モード光ファイバとの接続構造であって、前記分散補償光ファイバと単一モード光ファイバの間に、モードフィールド径が前記分散補償光ファイバのモードフィールド径と実質的に同じで、クラッドがフッ素ドープシリカからなり、コアが屈折率を高めるドーパントを含むシリカからなる中間光ファイバを介在させ、中間光ファイバの一端を前記分散補償光ファイバと融着接続すると共に、中間光ファイバの他端を前記単一モード光ファイバと融着接続し、中間光ファイバと単一モード光ファイバとの接続部における中間光ファイバのモードフィールド径を単一モード光ファイバのモードフィールド径に合うように拡大したことを特徴とする分散補償光ファイバの接続構造。

【請求項２】中間光ファイバは、クラッドの、単一モード光ファイバのモードフィールド径に相当する径より内側の層にフッ素がドープされ、それより外側の層にはフッ素が実質的にドープされていないものであることを特徴とする請求項１記載の分散補償光ファイバの接続構造。

【請求項３】クラッドが実質的に純シリカからなる分散補償光ファイバと、クラッドが実質的に純シリカからなる通常の単一モード光ファイバとの接続方法であって、前記分散補償光ファイバと単一モード光ファイバの間に、モードフィールド径が前記分散補償光ファイバのモードフィールド径と実質的に同じで、クラッドがフッ素ドープシリカからなり、コアが屈折率を高めるドーパントを含むシリカからなる中間光ファイバを介在させ、中間光ファイバの一端を前記分散補償光ファイバと融着接続すると共に、中間光ファイバの他端を前記単一モード光ファイバと融着接続した後、中間光ファイバと単一モード光ファイバとの接続部を加熱して、その接続部における中間光ファイバのモードフィールド径を単一モード光ファイバのモードフィールド径に合うように拡大することを特徴とする分散補償光ファイバの接続方法。

【請求項４】中間光ファイバとして、クラッドの、単一モード光ファイバのモードフィールド径に相当する径より内側の層にフッ素がドープされ、それより外側の層にはフッ素が実質的にドープされていない光ファイバを用いることを特徴とする請求項３記載の分散補償光ファイバの接続方法。

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存の伝送路を用いて１５５０ｎｍの高速通信を行うことが検討されている。しかしながら現在ひろく布設されている１３００ｎｍ零分散光ファイバは１５５０ｎｍ付近でのモード分散が１８ｐｓ／ｎｍ／ｋｍ程度あるため、１００ｋｍでは１８００ｐｓ／ｎｍに達し、高速通信を行う場合には何らかの分散補償手段が必要になる。

【０００３】分散補償手段として現在もっとも実用的な方法と考えられているのが、伝送路の途中に負の高分散特性をもつ分散補償光ファイバを挿入してモード分散を相殺する方法である。具体的には分散補償光ファイバを小さなパッケージにして、伝送装置に組み込むことが検討されている。

【０００４】負の高分散特性をもつ分散補償光ファイバは、Δ（比屈折率差）が３％前後と高く、コア径が２～３μｍと通常の単一モード光ファイバに比べて極端に小さい構造である。したがって分散補償光ファイバの１５５０ｎｍでのモードフィールド径は４．５～５．５μｍ程度となる。

【０００５】これに対し、１３００ｎｍ零分散光ファイバの１５５０ｎｍでのモードフィールド径は９～１１μｍであるから、この光ファイバと分散補償光ファイバをコネクタ接続すると、大きな接続損失が生じる。そこで、これを防ぐために、パッケージ内で分散補償光ファイバと通常の単一モード光ファイバとを融着接続して、パッケージから引き出されるリードは通常の単一モード光ファイバとし、１３００零分散光ファイバとのコネクタ接続を可能にしている。

【０００６】この場合、分散補償光ファイバと通常の単一モード光ファイバとの融着接続部は、接続後に加熱してコア内のＧｅを拡散させる処理（ＴＥＣ法）を施すことにより、分散補償光ファイバのモードフィールド径を拡大し、単一モード光ファイバのモードフィールド径に合わせるようにしている。これにより融着接続部の接続損失は大幅に低減でき、最終的なコネクタ入力からコネクタ出力までのトータル損失は、分散補償光ファイバに単にコネクタ付けしたものより格段に低減される。

【０００７】ところで分散補償光ファイバは、Δを大きくする必要から、コアに$GeO_2$を、クラッドにフッ素をそれぞれ高濃度でドープしている。このような分散補償光ファイバと通常の単一モード光ファイバ（リード用）とを融着接続して、その接続部を加熱した場合、分散補償光ファイバのフッ素ドープガラスの部分は軟化温

続部の接続損失を小さくすることが可能となるわけである。これが従来、分散補償光ファイバとリード用の単一モード光ファイバとの融着接続部で、接続損失を小さくできる理由である。

【0008】

【発明が解決しようとする課題】ところが最近、分散補償光ファイバとして、分散特性改善のため、コアが$GeO_2$高濃度ドープのセンターコアとフッ素ドープのサイドコアからなり、クラッドが純シリカからなる、W型と呼ばれる複雑な構造の光ファイバを使用することが検討されている。このような分散補償光ファイバは、フッ素をドープしたサイドコアの外径が5μm程度であり、クラッドが純シリカであるから、通常の単一モード光ファイバと融着接続した後、接続部を加熱しても、センターコアの$GeO_2$はフッ素をドープしたサイドコアまでしか拡散しない。もし$GeO_2$をクラッドまで拡散させようとして加熱時間を長くすれば、リード用の単一モード光ファイバでも同様な$GeO_2$の拡散が生じ、単一モード光ファイバのモードフィールド径も同様に拡大してしまう。

【0009】したがってクラッドが純シリカからなる分散補償光ファイバでは、クラッドが純シリカからなる通常の単一モード光ファイバとの融着接続部で、分散補償光ファイバだけ選択的にモードフィールド径を拡大することができず、接続損失を十分に低くすることができない、という問題があった。

【0010】本発明の目的は、クラッドが実質的に純シリカからなる分散補償光ファイバを、クラッドが実質的に純シリカからなる通常の単一モード光ファイバと、低損失で接続する手段を提供することにある。

【0011】

【課題を解決するための手段】この目的を達成するため本発明では、クラッドが実質的に純シリカからなる分散補償光ファイバと、クラッドが実質的に純シリカからなる通常の単一モード光ファイバとを接続する場合に、前記分散補償光ファイバと単一モード光ファイバの間に、モードフィールド径が前記分散補償光ファイバのモードフィールド径と実質的に同じで、クラッドがフッ素ドープシリカからなり、コアが屈折率を高めるドーパント（$GeO_2$等）を含むシリカからなる中間光ファイバを介在させる。そして中間光ファイバの一端を前記分散補償光ファイバと融着接続すると共に、中間光ファイバの

$O_2$等を高濃度にドープしたコア（又は$GeO_2$等を高濃度にドープしたセンターコアとフッ素ドープしたサイドコアからなるコア）1aの外周に、純シリカからなるクラッド1bを設けたものである。2は通常の単一モード光ファイバで、$GeO_2$等をドープしたコア2aの外周に、純シリカからなるクラッド2bを設けたものである。分散補償光ファイバ1のモードフィールド径は単一モード光ファイバ2のモードフィールド径より格段に小さい。3は中間光ファイバで、$GeO_2$等を高濃度にドープしたコア3aの外周に、フッ素をドープしたクラッド3bを設けたものである。

【0013】また符号4は分散補償光ファイバ1と中間光ファイバ3との融着接続部、5は中間光ファイバ3と単一モード光ファイバ2との融着接続部、6は中間光ファイバ3と単一モード光ファイバ2との接続部5で中間光ファイバ3のモードフィールド径を単一モード光ファイバ2のモードフィールド径に合うように拡大した部分である。

【0014】

【作用】分散補償光ファイバ1と中間光ファイバ3はモードフィールド径が実質的に同じであるから、この両者を通常の融着接続で0．1dB以下の低損失で接続することは容易である。

【0015】一方、中間光ファイバ3と通常の単一モード光ファイバ2はモードフィールド径が異なるが、中間光ファイバ3は、クラッドにフッ素がドープされ、コアに屈折率を高めるドーパント（$GeO_2$等）が含まれているため、加熱されると、単一モード光ファイバ2より速く、コアのドーパントがクラッドに拡散し、モードフィールド径が拡大する。したがって中間光ファイバ3と単一モード光ファイバ2との融着接続部5を加熱することにより、中間光ファイバ3のモードフィールド径を拡大し、単一モード光ファイバ2のモードフィールド径に合わせることができる。モードフィールド径を合わせた状態での接続損失は0．2dB以下にすることが可能である。したがって融着接続部が2箇所になってもトータルの接続損失はほぼ0．3dB以下にとどめることが可能である。

【0016】分散補償光ファイバと通常の単一モード光ファイバとを直接融着接続した場合の接続損失は0．8dB以上であるから、これに比較すると本発明は、接続損失を大幅に低減できる。

4%、モードフィールド径＝10μm。

③ 中間光ファイバ：

a．コアが$GeO_2$高濃度ドープシリカ〔Δ（＋）＝2．9〕、クラッドがフッ素ドープシリカ〔Δ（－）＝0．1〕。Δ＝3%、モードフィールド径＝5．0μm。

b．コアが$GeO_2$高濃度ドープシリカ〔Δ（＋）＝2．7〕、クラッドがフッ素ドープシリカ〔Δ（－）＝0．3〕。Δ＝3%、モードフィールド径＝5．0μm。

c．コアが$GeO_2$高濃度ドープシリカ〔Δ（＋）＝2．5〕、クラッドがフッ素ドープシリカ〔Δ（－）＝0．5〕。Δ＝3%、モードフィールド径＝5．0μm。

④ 通常の単一モード光ファイバ（伝送路用）：Δ＝0．3%、モードフィールド径＝10μm。

【0018】これらの光ファイバから次のようなサンプルを作製した。

サンプルA：①の分散補償光ファイバの両端に③－aの中間光ファイバを融着接続し、さらに中間光ファイバの外端に②の単一モード光ファイバを融着接続し、中間光ファイバと単一モード光ファイバの融着接続部を加熱して、中間光ファイバのモードフィールド径を拡大し、単一モード光ファイバのモードフィールド径に合わせたもの。

サンプルB：①の分散補償光ファイバの両端に③－bの中間光ファイバを融着接続し、さらに中間光ファイバの外端に②の単一モード光ファイバを融着接続し、中間光ファイバと単一モード光ファイバの融着接続部を加熱して、中間光ファイバのモードフィールド径を拡大し、単一モード光ファイバのモードフィールド径に合わせたもの。

サンプルC：①の分散補償光ファイバの両端に③－cの中間光ファイバを融着接続し、さらに中間光ファイバの外端に②の単一モード光ファイバを融着接続し、中間光ファイバと単一モード光ファイバの融着接続部を加熱して、中間光ファイバのモードフィールド径を拡大し、単一モード光ファイバのモードフィールド径に合わせたもの。

【0019】各サンプルの融着接続部の接続損失を測定した結果は表1のとおりであった。この結果によれば、中間光ファイバのクラッドへのフッ素ドープ量は、微量でも接続損失の低減効果がある（サンプルA）が、Δ（－）＝0．3%以上（サンプルB、C）になると、接続損失の低減効果が良好なレベルで安定することが分かる。

【0020】

【表1】

| | ①と③間の接続損失 | ③と②間の接続損失 | 合計接続損失 |
|---|---|---|---|
| サンプルA | 0．10dB | 0．35dB | 0．45dB |
| サンプルB | 0．13 | 0．15 | 0．28 |
| サンプルC | 0．15 | 0．15 | 0．25 |

【0021】また各サンプルの両端にコネクタを取り付け、④の単一モード光ファイバとコネクタ接続した結果、分散補償光ファイバの片側におけるコネクタを含む合計接続損失は0．65～0．45dBであった。この結果は、次の比較例1、2に比べ、接続損失がほぼ半分以下という良好なものである。

【0022】〔比較例1〕実施例1の①の分散補償光ファイバの両端にコネクタを取り付け、④の単一モード光ファイバとコネクタ接続を行ったところ、接続損失は片側で1．2dBと大きな値を示した。

【0023】〔比較例2〕実施例1の①の分散補償光ファ

以下にすることができなかった。

【0024】また、実施例1の①の分散補償光ファイバの両端に、②のリード用単一モード光ファイバを融着接続し、融着接続部を加熱して接続損失を1．0dBとしたサンプルの両端にコネクタを取り付けて、④の単一モード光ファイバとコネクタ接続したところ、分散補償光ファイバの片側におけるコネクタを含む合計接続損失は最小で1．2dBであった。

【0025】〔実施例2〕実施例1の①の分散補償光ファイバの代わりに次の分散補償光ファイバを用意した。

⑤ 分散補償光ファイバ：センターコアが$GeO_2$高濃

中間光ファイバを融着接続し、さらに中間光ファイバの外端に②の単一モード光ファイバを融着接続し，中間光ファイバと単一モード光ファイバの融着接続部を加熱して，中間光ファイバのモードフィールド径を拡大し、単一モード光ファイバのモードフィールド径に合わせたもの。

サンプルＥ：⑤の分散補償光ファイバの両端に③－ｂの中間光ファイバを融着接続し、さらに中間光ファイバの外端に②の単一モード光ファイバを融着接続し，中間光ファイバと単一モード光ファイバの融着接続部を加熱して，中間光ファイバのモードフィールド径を拡大し、単一モード光ファイバのモードフィールド径に合わせたもの。

サンプルＦ：⑤の分散補償光ファイバの両端に③－ｃの中間光ファイバを融着接続し、さらに中間光ファイバの＊

＊外端に②の単一モード光ファイバを融着接続し，中間光ファイバと単一モード光ファイバの融着接続部を加熱して，中間光ファイバのモードフィールド径を拡大し、単一モード光ファイバのモードフィールド径に合わせたもの。

【００２７】各サンプルの融着接続部の接続損失を測定した結果は表２のとおりであった。この結果からも、中間光ファイバのクラッドへのフッ素ドープ量は，微量でも接続損失の低減効果がある（サンプルＤ）が，Δ（－）＝０．３％以上（サンプルＥ，Ｆ）になると接続損失の低減効果が良好なレベルで安定することが分かる。

【００２８】

【表２】

| | ⑤と③間の接続損失 | ③と②間の接続損失 | 合計接続損失 |
|---|---|---|---|
| サンプルＤ | ０．１０ｄＢ | ０．３５ｄＢ | ０．４５ｄＢ |
| サンプルＥ | ０．１１ | ０．１５ | ０．２６ |
| サンプルＦ | ０．１３ | ０．１５ | ０．２８ |

【００２９】また各サンプルの両端にコネクタを取り付け，実施例１の④の単一モード光ファイバとコネクタ接続した結果、分散補償光ファイバの片側におけるコネクタを含む合計接続損失は０．６５～０．４２ｄＢであった。この結果は，次の比較例３、４に比べ、接続損失がほぼ半分以下という良好なものである。

【００３０】〔比較例３〕実施例２の⑤の分散補償光ファイバの両端にコネクタを取り付け，実施例１の④の単一モード光ファイバとコネクタ接続を行ったところ、接続損失は片端で１．３ｄＢと大きな値を示した。

【００３１】〔比較例４〕実施例２の⑤の分散補償光ファイバの両端に，実施例１の②のリード用単一モード光ファイバを融着接続したところ、接続損失は片端で１．１ｄＢと大きな値を示した。また融着接続部を加熱しても接続損失は低下せず、加熱を続けると、単一モード光ファイバのコアの$GeO_2$の拡散により接続損失が１．３ｄＢ以上になってしまった。

【００３２】また、実施例２の⑤の分散補償光ファイバの両端に、実施例１の②のリード用単一モード光ファイバを融着接続したサンプルの両端にコネクタを取り付け

はフッ素が実質的にドープされていない光ファイバを使用することが望ましい。このようにすると単一モード光ファイバとの融着接続部を加熱した際に、中間光ファイバのコアのドーパントがクラッドに拡散する範囲が制限され，中間光ファイバのモードフィールド径を，単一モード光ファイバのモードフィールド径に合わせることが容易になる。

【００３４】

【発明の効果】以上説明したように本発明によれば、クラッドが実質的に純シリカからなる分散補償光ファイバを，クラッドが実質的に純シリカからなる通常の単一モード光ファイバと接続する場合に、低損失で接続できるという効果がある。

【図面の簡単な説明】

【図１】 本発明による分散補償光ファイバの接続構造を示す説明図。

【符号の説明】

１：分散補償光ファイバ

１ａ：コア

１ｂ：クラッド

【図１】